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EFFECT OF SURFACE EXPOSURE TIME (SET) ON STRENGTH OF ADHESIVE BONDS TO ALUMINUM

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Surface exposure times (SET) at 23°C and 50% RH for 2024-T3 aluminum subsequently bonded with EC-2214 adhesive did not affect the bond strength for SET up to 30 days. SET at 54°C and 95 ± 5% RH gave much lower bond strengths that did not further change with increasing SET. The difference in strength is believed to be due to the formation of a hydrated aluminum oxide on the aluminum surface at 54°C and 95 ± 5% RH. This hydrated oxide functions as a weak boundary layer.		

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INTRODUCTION

Earlier work on several aluminum alloys in these laboratories (refs. 1 and 2) has indicated that surface exposure times (SET) up to 30 days have little or no effect on subsequent adhesive bond strength and durability. At first glance these results would appear to be at odds with those of Smith and Kaelble (ref. 3). The latter authors found an initial marked drop in strength with SET, followed by a leveling-off. However, bond strengths in reference 3 were measured after using SET conditions of 54°C (129°F) and 95% RH. The SET conditions in references 1 and 2 were a better approximation of shop storage conditions (23°C (73°F) and 50% RH). In an effort to reconcile these results we have selected a system for which we had previously determined strength-SET data (refs. 1 and 2) and have carried out additional studies using 54°C and 95% RH as the SET conditions.

RESULTS AND DISCUSSION

The results for the 2024-T3/EC-2214 system are shown in figure 1. This figure shows clearly that there are marked differences in strength behavior, depending on which SET condition is used. At 23°C and 50% RH there appears to be no significant difference in strength for SET times up to 30 days. However, at 54°C and 95 ± 5% RH SET conditions, strength initially falls off precipitously with SET and then levels off. These results generally are in accord with the earlier work (refs. 1 through 3).

It has been reported (refs. 4 and 5) that aluminum in hot water forms a hydrated oxide layer that is cohesively weak. Although adhesives bond readily to this oxide, it serves as a weak boundary layer and markedly reduces the resultant apparent strength of the bond. Under the elevated temperature and high humidity conditions of 54°C and 95% RH SET it seems reasonable to suppose that such a weak boundary layer is formed. This would be especially favored in the case of condensing humidity.* This weak boundary layer would then account for the marked strength reduction. Smith and Kaelble (ref. 3, pp 63 and 64) also report evidence for failure in a thick oxide layer after SET at 54°C and 95 through 100% RH. They also found indications that aging had caused a structural, as well as a thickness, change in the oxide.

*W. Russell, private communication, 1979.

Linear Weibull distribution plots (ref. 6) are shown in figure 2. All of the data for each SET condition appear to fall within the same distribution. The correlation coefficients are 0.983 for SET at 23°C and 50% RH and 0.976 for SET at 54°C and 95% RH.

EXPERIMENTAL PROCEDURES

Materials

The aluminum alloy used was 2024-T3 bare, 0.025 cm (0.063 in.) thick.

EC-2214 is a modified epoxy paste manufactured by the Minnesota Mining and Manufacturing (3M) Company. It has a viscosity at room temperature suitable for trowel application. Curing is achieved at 121°C (250°F) in 40 minutes. It requires only contact pressure for joint formation.

Surface Preparation

The panels were washed with acetone and treated by immersion in a solution containing one part by weight (pbw) sodium dichromate, 10 pbw concentrated sulfuric acid, and 30 pbw deionized water. The solution temperature was 60°C (140°F), the immersion time 10 minutes. The treated panels were rinsed for 1 to 2 minutes in running tap water at 40°C (104°F), rinsed with deionized water at room temperature, and dried in an air-circulating oven at 60°C (140°F).

Surface Exposure Before Bonding

All but the control specimens were conditioned in a controlled environment of 54°C (129°F) and 95 ± 5% RH for periods of 2 hours, 4 hours, 15 hours, 24 hours, 48 hours, and 72 hours.

Bonding Procedure

The panels to be bonded were removed from their conditioning environments no sooner than 30 minutes before bonding. For the control specimens (0 hours conditioning) bonding was effected after the oven-drying. The EC-2214 was brought up to room temperature before application to the panels by means of a wooden tongue depressor. Curing was accomplished in jigs to control the overlap [1.27 cm (1/2 in.)].

Method of Testing

A Baldwin Universal Test Machine was used for load applications. The load rate was 16.5 MPa (2400 psi) per minute.

CONCLUSIONS

1. For the 2024-T3/EC-2214 system SET at 23°C and 50% RH gave strengths significantly higher than SET at 54°C and 95% RH.
2. The difference in strengths is believed to be due to formation of a hydrated aluminum oxide on the aluminum surface at 54°C and 95% RH. This hydrated oxide functions as a weak boundary layer.

REFERENCES

1. D. W. Levi, W. C. Tanner, M. C. Ross, R. F. Wegman, and M. J. Bodnar, "Effect of Surface Exposure Time on Bonds to Aluminum," J. Applied Polymer Sci 20, p 1475 (1976).
2. D. W. Levi, "Durability of Adhesive Bonds to Aluminum," J. Applied Polymer Sci: Applied Polymer Symposium 32, p 189 (1977).
3. T. Smith and D. H. Kaelble, "Mechanisms of Adhesion Failure Between Polymers and Metallic Substrates: Aluminum 2024-T3 and Titanium 6Al-4V with HT424 Adhesive," AFML-TR-74-73, Wright Patterson AFB, Dayton, OH (1974).
4. S. Wernick and R. Pinner, The Surface Treatment and Finishing of Aluminum, Robert Draper Ltd, Teddington, G.B., p 197-198, 1964.
5. R. F. Wegman, "A Study of Adhesive Joint Failures by Evaporative Rate Analysis," Technical Report 3746, Picatinny Arsenal, Dover, NJ, 1968.
6. C. A. Moyer, J. J. Bush, and B. T. Ruley, "The Weibull Distribution Function for Fatigue Life," Material Research and Standards 2, p 405 (1962).

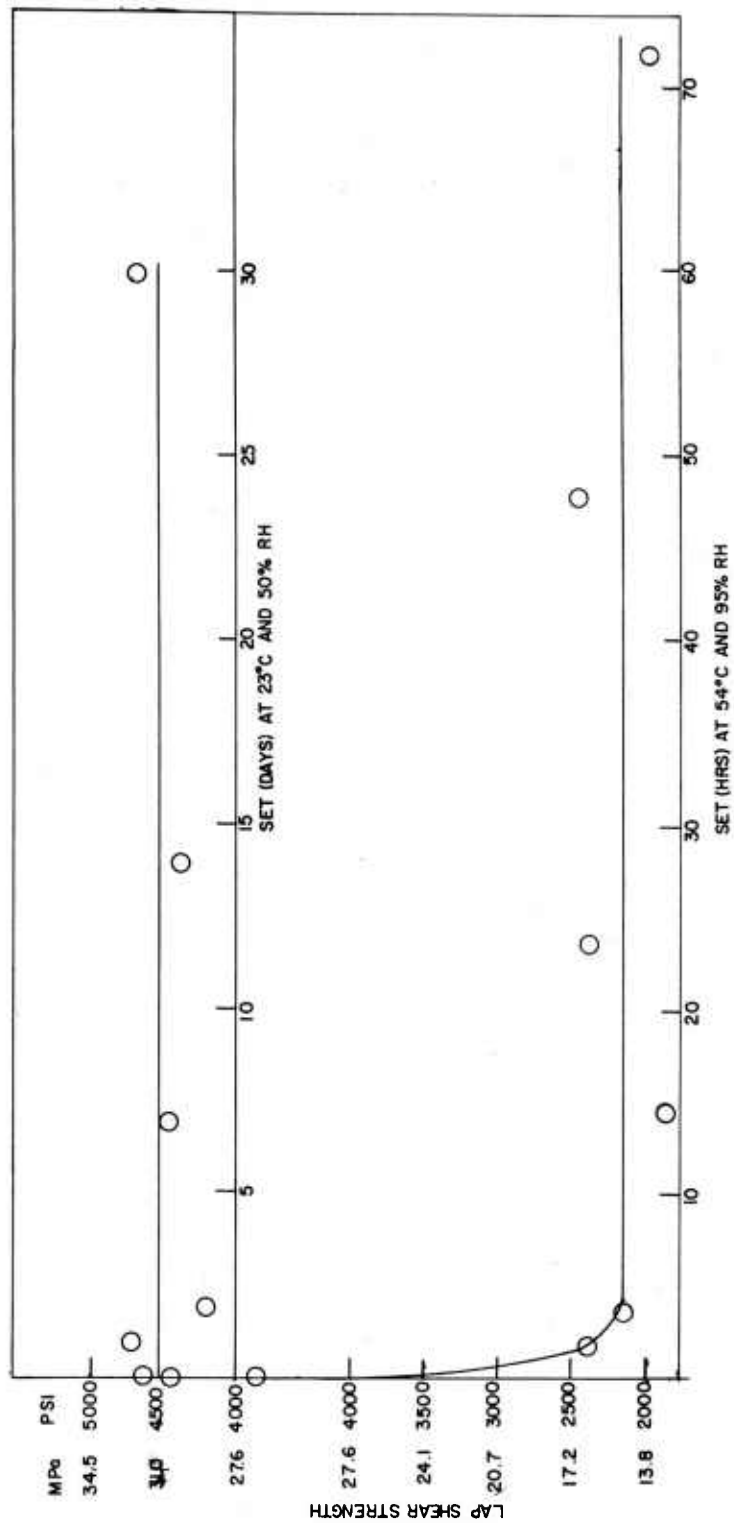


Figure 1. Comparison of strength data at two SET conditions.

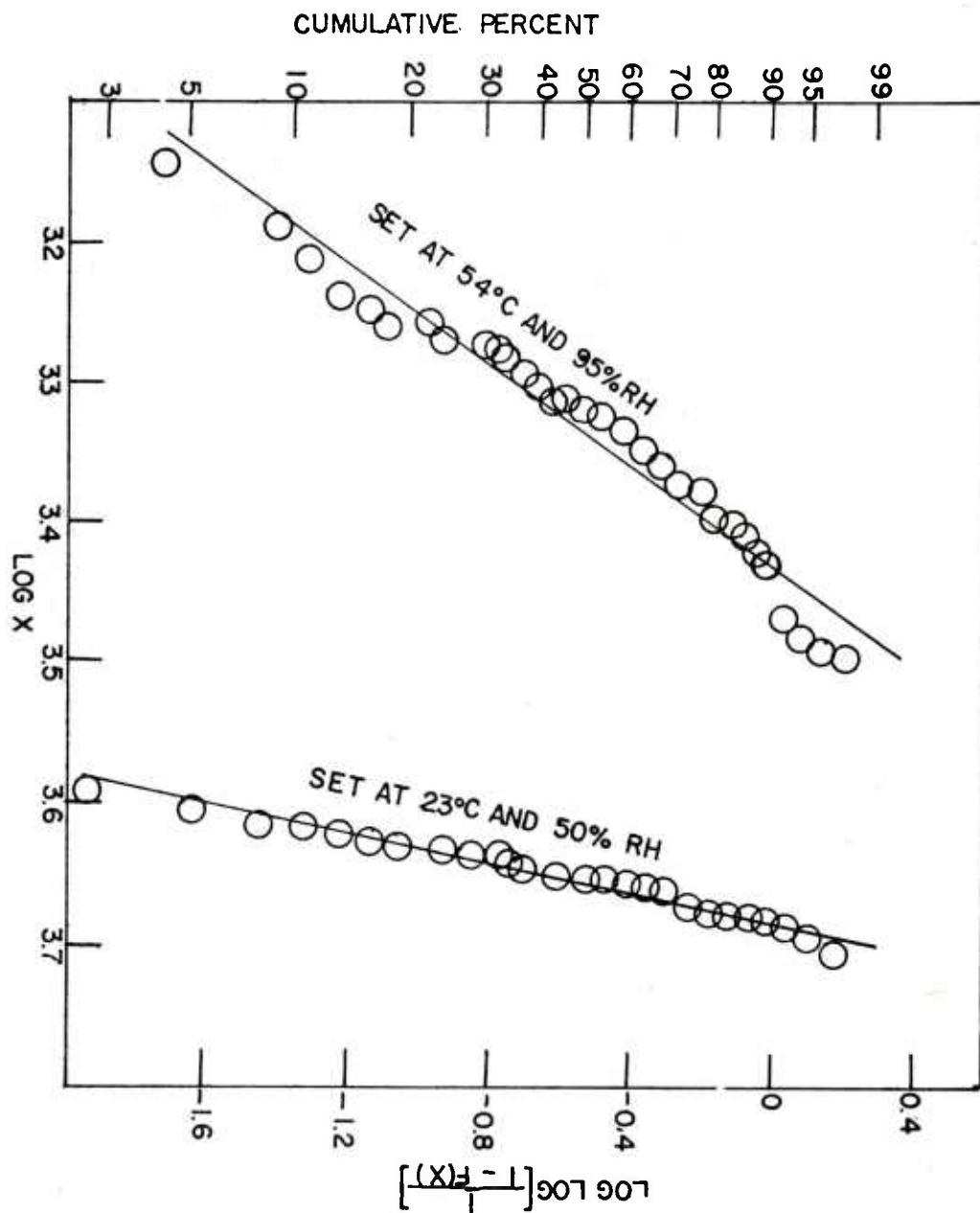


Figure 2. Linear Weibull plots for two SET conditions

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